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DECREASING THE COST OF CONSTRUCTING THERMAL ELECTRIC POWER STATIONS IN THE USSR

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The solution of a concrete technological problem must be based on computations that can confirm the economic usefulness of the task.

In the case of newly constructed electric power stations, the economic logic in the solution of technological problems, with other conditions being equal, is determined with the aid of cost indexes per one rated kw (specific capital investment) and the production cost of one delivered kwh (specific operating expenses). These 2 indexes must be closely examined in order to decide which one of them is the decisive factor, even when a certain interrelationship exists between them.

Index of Capital Investment and Operating Expenses

The structure of electric power cost, delivered by the busbars of the electric power station, broken down into individual elements of expense and expressed in the terms of the 1950 price index would appear as follows.

	With 6,000 cal/kg Fuel	With 3,000 cal/kg Fuel
Fuel	60 %	70 %
Amortization and overhaul	18 %	13 %
Wages and wage increments	11 %	8 %
Power consumption for the station's own needs	11 %	9 %
	100 %	100 %

The following conclusions can be reached from the interrelationship of the above factors:

1. The magnitude of the "amortization and overhaul" element, which is a direct function of the volume of capital investment, indicates that 18 to 13% of the cost of the delivered kwh depends directly on the cost of the rated kw. Consequently, if other factors affecting the reduction of specific capital investment remain unchanged, operationg expenses will be reduced by 18 to 13% of the level of reduction of the former; for example, if the cost of one rated kw is reduced 10%, the cost of one delivered kwh will be reduced 1.8 to 1.3%.

2. The ratio of the "fuel" and "amortization and overhaul" factors of 3.3:1 (60 and 18%) indicates that an increase in capital investment for the purpose of reducing specific expenditures for fuel is economically sound if the degree of this increase is smaller than 3 times the magnitude of the fuel saving. In order to achieve a fuel saving of 10%, an increase in capital investment is permissible up to 33%.

3. The ratio of "wages" to "amortization and overhaul" is 1:1.66 (11 and 18%, which determines the limits for the increase of capital investment, in connection with the decrease of expenses of personnel; for example,

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to reduce these expenses by 10%, it is permissible to increase capital investment up to 6%.

These ratios must be considered during the examination of questions concerning the cost of construction and the comparison of the volume of capital investment with the magnitude of operating expenses so that the most economical plan for the construction of an electric power station can be selected. However, it is necessary to remember that arithmetical relationships are relative and the magnitude of the components which make up cost does not always reflect their significance in the national economy.

The volume of capital investment in the socialist economy is limited by that portion of national income which, based on the national economy program, is assigned as savings of primary funds for a given period. For this reason, capital investment may not be expanded beyond the predetermined limits, even if such an expansion would result in reduced operating expenses. In view of a fixed amount that is appropriated and a predetermined increase in power capacity, a preference may sometimes be given to the plan that has a lower volume of capital investment and a higher level of operating expense. The problem of conserving fuel depends on the sources of fuel. In certain cases, this may call for the selection of a less favorable plan (in terms of capital investment) in order to reduce fuel consumption or to utilize the types of fuel available locally.

Reduction in the number of personnel, resulting from the mechanization of labor processes, has as its aim not only increase in labor productivity but also improvement of working conditions but in a socialist economy system, that cannot be made a sole factor for profit-making.

The ever-increasing demand for electric power and the pressure for further supply of electric power, often forces an electric power station to reduce the consumption of electric power for its own needs below the limits set by the cost reduction program.

In approaching the problem of reduced construction costs, one must examine the cost indexes of one rated kw and one deliverd kwhr, giving due allowance to the fact that these ratios are relative.

Methods for the Reduction of Construction Costs

The principal methods for the reduction of construction costs may be grouped as follows: selection of the most economical site; increase of total capacity of the electric power station; increase of the capacity of individual components; improvement in the efficiency of the equipment; accelleration of construction schedules.

Site Selection

The selection of a site, that is, its territorial location and its geological conditions, governs a significant portion of the expenses incurred in the construction of an electric power station, namely:

(a) Acquisition of the site; dismantling of existing structures and resettlement of inhabitants; planning; excavating, grading, and safety measures such as precautions against ground water.

(b) Installation of a water supply system and utilization of natural or artificial water cooling agents, depending on available water resources.

(c) Construction of roads, depending on location of main highways with due consideration of the terrain and ground conditions of the area.

The extent of operating expenses is affected, in turn, by the location of the site and its distance from fuel sources, as well as transmission facilities for the electric power generated (location of consumers of the power).

For electric power stations slated for construction in the period from 1953 to 1955, the average share of expenses that are governed by the selection of the site, in construction costs for stations with a capacity of over 300,000 kw is shown in Table 1.

TABLE 1

	% overall construction cost		% cost of construction operations	
	Maximum	Minimum	Maximum	Minimum
Site acquisition and planning	3.3	0.5	5.7	1.1
Water supply and safety measures	22.2	7.5	39.2	17.7
Access roads	5.1	4.0	8.7	9.9
Total	30.6	12.0	53.6	28.7

Figures in Table 1 indicated how very important the selection of the most economical site can be. Over 18% of cost reductions are possible, while the cost of construction operations, which in turn affects labor needs and length of construction, can be reduced by 25%. Furthermore, an 18% reduction in construction costs as shown above will result in a 3.2% reduction of operating expense.

The selection of the best possible construction site is governed by the natural conditions of the region in which the projected power station is to be constructed. Circumstances to be considered are the need for maximum proximity to fuel sources and closeness of the power station to consumers.

Selection of the construction site constitutes a complex technical and economic problem, the successful solution of which determines construction costs and affects the level of operating expenses. Therefore the search for the best possible construction sites in every rayon of the USSR is a very important task. This task must be carried out not on individual basis -- every time a power station is to be constructed -- but must be done systematically on a planned basis, and must cover the entire territory of the USSR, particularly those regions which are close to sources of fuel. A planned system for the selection of best possible construction sites should be instituted.

Increase of Power Station Capacity

Considerable reductions in the costs of construction may be achieved through the increase of power station capacities, even though the individual capacity of the equipment is retained. Expenses of construction increase to a lesser degree than total capacity of installed equipment, thus the cost per rated kw and per kwh is reduced.

Construction costs can be classified into three groups, with respect to dependence on capacity.

I. Expenses which constitute about 50% of total cost and which increase in proportion with capacity increase.

Among these are the costs of all basic equipment and costs of construction of the primary installations. A portion of these expenses, such as those of constructing the main walls, remains unchanged, while others, such as costs of equipping shops, providing auxiliary pumps, freight elevators, etc do not directly depend on the capacity of the primary equipment. However, the ratio of this portion of the expense and its influence on the reduction of expenses is not significant. Furthermore to the extent that no nu er of mechanisms is increased and the main structure is lengthened, addit nal expenses are incurred for additional lengths of cables and ducts and thus the relative reduction of the nonproportional portion of the expenses is compensated for.

II. Expenses which constitute about 25% of total cost and which do not increase to the same extent as costs of increasing the capacity, but increase only about 3% for each 100,000 kw of capacity increase.

Among such expenses are costs of electric and fuel supply, water supply, and other auxiliary services.

The relative reduction of these expenses, when overall capacity of the power station increases, is achieved through better utilization of available resources, through use of more productive equipment, at a time when factors affecting operation of the station as a whole remain unchanged. For example savings result when more electric power is used while general electric distribution panels remain the same.

With respect to fuel, the increase in the capacity of power station and the hourly consumption of fuel does not require a corresponding increase in fuel lines or in the efficiency of the fuel supply installations. When fuel consumption is increased from 250 to 500t per hour, that is, when fuel consumption is doubled the bridge loader in the fuel storage area with a normal span of 60 m must be replaced with one having a span of 76.2 m. The cost of the latter is 70% higher than that of the former.

Water-cooling provisions to service power stations of increased capacity frequently require not so much the extension of water lines, but only the increase of the diameter of the pipes. Frequently existing pumping facilities are retained and only one additional pump is installed. Nor does the extent of waste disposal pipes change with increased power station capacity; only the pipe diameter has to be increased.

Operational expenses, such as labor costs, do not basically depend on the capacity of the power station but on the number of the operating personnel (the ratio of which decreases with the increase of station capacity). The central overhaul shops for lubrication personnel can service a station of increased capacity by using available equipment more efficiently.

III. Expenses which constitute some 25% of total cost and which do not increase in proportion with capacity increase by more than 5% per 100,000 kw of increased capacity.

Among such costs are costs of access roads, communication equipment, improvement of the site, housing, and construction of temporary structures (auxiliary structures designed to facilitate construction operations, installation of construction machinery, and operation of construction equipment).

Access roads, that is, roads leading from main highways to the construction site, obviously do not depend on the capacity of the station under construction. Certain auxiliary facilities are taxed more heavily because of the increased freight handling. It is conceivable that in some cases auxiliary access roads must be constructed.

Intrastation communications depend on the size of the construction site, and their cost increases to a considerably lesser degree against the increase in station capacity. If a power station of 300,000 kw capacity were to be assumed to require an area of 100 units for the production of 1,000 kw of power, comparable areas for the production of 1,000 kw needed by higher capacity stations would be as follows:

600,000 kw capacity	79%
900,000 kw capacity	68%
1,200,000 kw capacity	61%

Thus a 400% increase in capacity would require only a 39% increase in area; there would be corresponding small increases in the extent of all other intrastation installations and services.

The extent of housing required depends on the number of personnel. If a personnel coefficient, that is, the number of personnel required per 1,000 kw produced by a 300,000 kw station, were to be equal to 100, a comparable coefficient for power stations of higher capacity would be as follows:

600,000 kw capacity	61%
900,000 kw capacity	47%
1,200,000 kw capacity	41%

Thus a reduction of 59% in the personnel coefficient would result in an equal reduction of expenses for the construction of personnel housing facilities.

The extent of temporary construction is directly proportional to the volume of construction and installation work.

As indicated earlier, the increase in capacity and volume of construction results in a reduction of the proportionate size of a number of expenditures related primarily to construction and installation work. Corresponding decreases result in the extent of temporary construction.

The comparison figures given for power stations of various capacities using similar equipment and fuel would indicate that the following changes result in the different expenditure groups (Table 2).

TABLE 2

Expenditure Group	Power Station Capacity in 1,000 kw			
	450	600	900	1,200
I	100	99	99	99
II	100	95	87	72
III	100	83	73	63
	100	94	87	82

As can be seen, a capacity increase of 750,000 kw resulted in specific cost reduction of 18%, or an average of 2.5% per 100,000 kw.

A direct consequence of the reduction in construction costs and in the personnel coefficient is the reduction in the production cost per kwh, at the expense of the chapter headings "amortization and overhaul" and "salaries." These reductions appear as follows (in % of production cost for a power station of 450,000 kw capacity):

600,000 kw capacity	1.5
900,000 kw capacity	3.7
1,200,000 kw capacity	5.2

While there are obvious advantages in constructing power stations of higher capacity, the increasing of the capacity of stations through the increase of individual units of primary equipment encounters certain obstacles and is not economical beyond a certain point.

Among such obstacles is the difficulty of organizing the operation of a large number of machinery units. An installation using turbines of 150,000 kw capacity and boilers of 270 t per hour capacity, in a power station of 1,800,000 kw capacity, requires a total of 36 individual units, which would occupy a space 500 m long.

The organization of construction and installation operations becomes very complex because of the large number of workers that have to work in a small area.

The increase in the capacity of individual equipments will overcome these obstables and will make additional construction cost reductions possible.

Increase in the Individual Capacity of Equipment

Construction cost reductions resulting from the increase in individual equipment capacity appear from the ratio of the increase in price of basic types of equipment to the degree of its increase in capacity. As can be seen from current price schedules, a 100% increase in capacity results in the following price increases:

turbines	55%
boilers	65%
generators	60%
power transformers	45%

Proportional reductions result from the reduced volume of structures and auxiliary equipment.

One 100% increase in turbine capacity results in an increase of area occupied by the turbine and consequently of cubic volume of machine room space of only 40%; a comparable figure of 35% applies to boilers of increased capacity and corresponding required additional boiler room space. The volume of the building required per kw in a 300,000 kw station amounts to 1.38 cu when turbines of the VK-50 type are used and to 1.18 cu m or 15% less, when turbines of the VK-100 type are installed.

An increase in the capacity of boilers makes it possible to introduce a system of turbogenerator-boiler grouping, which along with the reductions in the cost of the equipment, reduces the length of necessary piping.

On the whole, if one were to compare costs of electric power stations with 1,200,000 kw capacity operating with 100,000 kw turbines and 230 t per hour boilers with costs of a similar power station using 200,000 kw turbines in blocks equipped with one boiler each of corresponding capacity the overall cost of the construction and equipment of the latter power station would be 40 to 45% lower. Considering that the cost of this principal installation constitutes about 50% of the overall cost of the entire power station, the above reductions would constitute about 20% of overall cost.

The number of individual equipments in the above example would be reduced from 36 to 12. Correspondingly management of the construction operation and speed of construction would improve.

Increased Efficiency of Equipment

The introduction of thermal power equipment with high steam capacity has always appeared as a favorable measure for the reduction of power costs through fuel savings. Further increase in steam capacity would make it possible to exceed the standard achieved in the past.

In spite of the fact that the recently introduced turbo-and boiler installations with super high pressure (170 atm and 575°C) are still expensive (until such time as they can be manufactured by domestic industry in quantity), the installation of this equipment will result in significant savings.

The cost of constructing a 600,000 kw power station with high pressure steam equipment is 11.5% higher than that of constructing a power station of equal capacity but with 90 atmospheres of pressure at 500°C. Thus a corresponding increase in operating expenses of 2% will result. Simultaneously, as a result of a 10% reduction in the fuel expense, electric power costs will decrease 6%. Thus the use of high pressure steam will reduce the cost per kw by 4%. The period of amortization of additional capital investment is 8.5 years.

Acceleration of Construction Schedules

There is no need for stretching the enormous significance to the national economy of the acceleration of construction rates and the production of electric power at a time when demands for power are so great. It is difficult to present figures to illustrate the economic advantages of this, since one would have to determine the economic effects resulting from increased production and the acceleration of the turnover from incomplete capital construction.

In the acceleration of the rate of construction, the reduction of the preparatory period which takes as much as 35% of total construction time, is of utmost importance. This is further helped to a large extent by the industrialization of construction processes, the use of prefabricated components, demountable and portable temporary structures, and overall mechanization of building operations. In turn this will result in the reduction in the number of constructions and installation men required, and the amount of housing needed by them.

The introduction of modern technological methods in production operations, the reduction in the number of auxiliary installations and men required at the site, together with the reduction in preparatory time needed, will help reduce expenses of temporary construction which currently amount to as much as 18% of the cost of permanent constructions.

More than half of the expense for temporary construction is utilized in the provision of housing for construction and installation men. If in the enterprises of other branches of industry the number of workers engaged in construction does not exceed the number of permanent personnel, and if the former workers can be housed in quarters provided for permanent personnel, the comparable ratios in the construction of power stations (that is, ratio of construction workers to that of operating personnel, excluding dependents) is 6:1. Only 15% of these can be housed in quarters provided for permanent personnel; during the first year od construction the remainder must be provided for with temporary housing costing as much as 10% of permanent construction.

Growth of labor productivity resulting from the mechanization of construction processes and from the application of semifinished components, and the removal of the operation involving the manufacture of semifinished components from the construction site to the plant, make it possible to reduce at the end of the Sixth Five-Year Plan the number of workers by almost 50%; in other words, construction costs decrease 5%.

We have not touched upon a number of other measures designed to reduce construction costs; these include automatization of production and reduction of number of workers, reduction of the volume of buildings, reduction of power consumption by the station and so forth. It is however clear that possibilities exist for the reduction in the cost of constructing power stations by 30 to 40%, and 10 to 15% reduction in the production cost of electric power. This means that at the same level of expenditures it is possible to increase 30 to 40% the capacity of power stations currently under construction and to reduce the cost of producing power by many million rubles. The successful solution of this unique task is the responsibility of design and construction organizations and of the industry engaged in the production of power generating equipment.

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